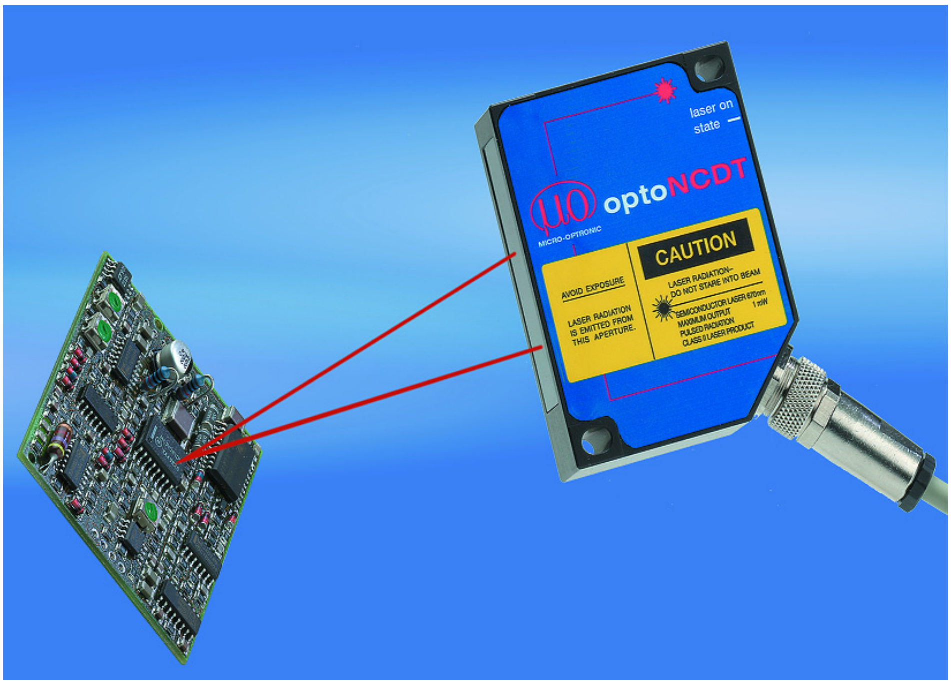
Contactless Distance Measurement

Sensors and principles

By J. Häuser

Contactless distance measurement is becoming more and more important in analysing vibration, alignment, position or bending. This article explains the most popular measurement methods and discusses their applicability.



Contactless distance measurement finds many practical applications: if the motion of an object would be damped or otherwise affected by coupled mass or the force exerted by a measurement device; when sensitive surfaces must not be damaged; or when rapid motion must be tracked.

Such testing and measurement tasks are commonplace in research and development, automation, quality control and machine control applications. For all these tasks a large number of companies offer numerous models of sensor employing various measurement principles. Three methods of contactless distance measurement have become dominant in the last few years: the eddy current principle, the capacitive principle and the optical triangulation principle.

THE EDDY CURRENT PRINCIPLE

The eddy current principle has special status in the class of inductive measurement methods. The effect is based on the dissipation of energy stored in a resonant circuit when eddy currents are induced in a nearby electrically conductive metallic object.

If, as shown in **Figure 1**, a metal plate is brought near to a coil fed with a high frequency alternating current, the electromagnetic field will induce eddy currents in the plate. By Lenz's law, the field due to the eddy current opposes the inducing field. The consequent energy loss changes the effective inductance of the sensor coil. Hence the amplitude of oscillations in the sensor coil changes as a function of the distance from the measured object (the metal plate). This principle, also known as the ‘eddy loss principle’, requires an oscillator with stable amplitude and frequency, usually operated in the range 1 MHz to 2 MHz. An air-cored (rather than ferrite-cored) coil is used.

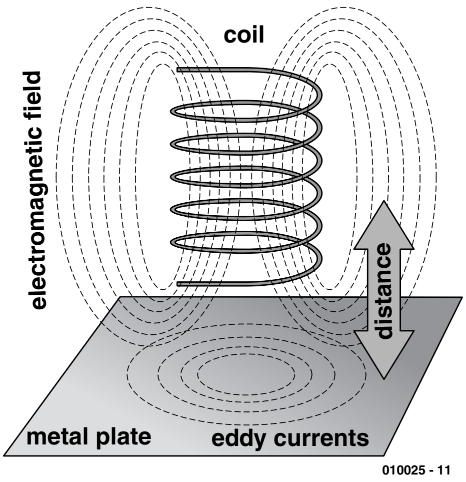


Figure 1. The eddy current principle.

Table I: Comparison of contactless measurement principles

Eddy current principle

Advantages

- Works with all electrically conductive metals whether ferromagnetic or not
- Small sensor
- Insensitive to dirt, dust, moisture, oil, dielectric substances in measurement gap
- Usable in electromagnetically sensitive applications
- Wide operating temperature range
- High accuracy

Limitations

- Output signal and linearity dependent on electrical and magnetic properties of materials used
- Individual linearisation and calibration required
- High oscillator frequency limits sensor cable length to 12 to 18 m.
- Sensor diameter (and measurement patch diameter) increase as maximum range is increased.

Capacitive principle

Advantages

- Independent of metal used in measured object: sensitivity and linearity remain the same.
- High temperature stability, as conductivity changes due to temperature have no effect.
- Also usable with non-conductive measured objects.

Limitations

- Sensitive to dielectric materials in the measurement gap, and hence only usable in clean and dry environments.
- Sensor cable must be short, owing to effect of cable capacitance on tuning of resonant circuit.
- Sensor diameter (and measurement patch diameter) increase as maximum range is increased.

Optical triangulation principle

Advantages

- Small measurement patch diameter.
- Sensor can be far from measured object.
- Large measurement range possible.
- Independent of materials used.

Limitations

- Limited usefulness with smooth surfaces (mirrors, glass, CDs, polished metals) or surfaces with low reflectivity (matt black surfaces)
- Limited usefulness with transparent or partially transparent surfaces (glass, ceramics, plastics such as Teflon).
- Space through which beam passes must be unobstructed and free of dust.

THE CAPACITIVE PRINCIPLE

The capacitive contactless distance measurement principle is based on the theory of the ideal plate capacitor (**Figure 2**). Changing the distance between the two plates leads to a change in its capacitance. In the measurement system the sensor and the measured object form the two plates. An alternating current of constant frequency is made to flow, and the amplitude of the alternating voltage across the two plates is proportional to the distance between the sensor and the measured object. At the same time an adjustable offset voltage is generated in the control electronics. After demodulation the two voltages are passed to a differential amplifier to generate the output as an analogue signal. By measuring the reactance X_C of the plate capacitor we obtain, without further linearisation, a directly proportional relationship. In practice, the sensor is constructed as a guard-ring capacitor and linearity is almost perfect, independent of the conductivity of the metal in the measured object.

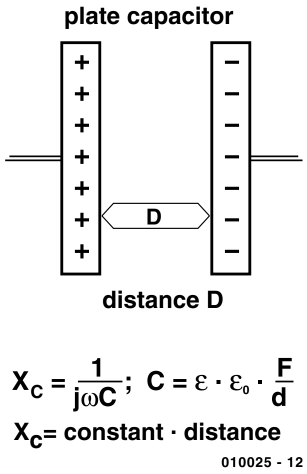


plate capacitor
D
distance D
$X_C = \frac{1}{j\omega C}$; $C = \varepsilon \cdot \varepsilon_0 \cdot \frac{F}{d}$
X_C= constant · distance
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Figure 2. The capacitive principle.

Capacitive sensors can also be used with insulating materials. Extra circuitry is required to obtain a linear output signal with such objects, and a stable dielectric constant is required to obtain a reliable characteristic.

THE OPTICAL TRIANGULATION PRINCIPLE

This principle, in which a pulsed laser beam is reflected off the surface of the measured

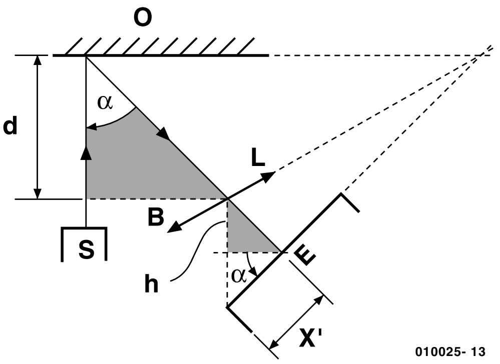

Figure 3. The optical triangulation principle.

object, is based on similar triangles, see **Figure 3**. The first triangle is the 'object triangle', between object and lens, and the second is the 'image triangle', between lens and detector. The detector is either a lateral effect diode or a CCD row sensor. A lens is required in the path of the diffuse rays reflected from the object to allow the angles of incidence and reflection to be different. This is the only way to resolve depth. Further, the detector must be set at a known angle. Here the Scheimpflug rule should be observed, which states that optimal focussing is obtained when the object, lens and detector planes intersect at a single point. Hence we have the following relationship:

$$\Delta d = \frac{B \cdot h}{\cos(\alpha)} \cdot \frac{1}{\Delta x}$$

Manufacturers convert the physical distance measured by the sensor into a standardised voltage range (for example 0 V to 10 V or 0 (4) mA to 20 mA). Alternatively, the value is digitised and transmitted over an RS232 or RS485 interface to a PC. With the aid of a suitable card for the PC (see 'PCI-Hosted Measurement Cards', *Elektor Electronics*, October 2000), and suitable software, an enormous range of test and measurement problems can be solved.

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Literature

Technical note T01d produced by:

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